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The effect of a low protein diet when fed to pregnant rats and sows upon the pre-natal and post-natal development of the young

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THE EFFECT OF A LOW PROTEIN DIET WHEN FED TO PREGNANT RATS AND SOWS UPON THE PRE-NATAL AND POST-NATAL DEVELOPMENT OF THE YOUNG

by

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INTRODUCTION

Considerable research involving different classes of animals has shown that the weight, vigor and general well being of the young at birth are affected by the quantity of protein in the ration of the mother during pregnancy. Experimental results point clearly to the fact that the lactating mother must have an adequate supply of protein in the diet if she is to nourish her young satisfactorily. There also is an abundance of evidence showing, among other things, the importance of feeding a properly balanced ration to young animals if maximum development is to be secured. In fact there is a vast amount of data showing the deleterious effect of an inadequate supply of proteins of correct quality on the development of the embryo and fetus, ability of the mother to nurse her young, and on the development of young after weaning.

A review of the literature fails, however, to reveal any experimental evidence showing whether or not feeding a ration containing an inadequate supply of protein during the period of pregnancy, only, would lessen the capacity of the mother to properly nurse her young or prevent the young from making satisfactory growth after weaning.

It was for the purpose of securing this information that the experiments, the results of which are reported in this manuscript, were undertaken.

REVIEW OF LITERATURE

A. Effect of Protein Intake of Mother on Birth Weight and Size of Litter in Swine

Evvard[4] conducted an experiment using five Duroc-Jersey gilts to the lot, in which a ration of mixed corn, mostly yellow, was compared with corn supplemented with various protein feeds. The gilts were started on the experiment at the time of breeding and continued thereon until after farrowing. Sodium chloride and other minerals were accessible to the sows at all times. The following table summarizes the results of this experiment.

Table I

Protein Supplements to Corn for Pregnant Gilts

Lot	Daily ration fed each gilt	Average number pigs farrowed each litter	Average birth weight (pounds)	Per cent of strong pigs
I.	3.65 lb. corn	7.6	1.74	68.42
II.	3.21 lb. corn 0.13 lb. meat-meal	7.4	2.01	91.89
III.	2.74 lb. corn 0.43 lb. meat-meal	8.8	2.23	93.18
IV.	2.73 lb. corn 1.07 lb. meal mixture*. . .	10.6	1.84	83.02
V.	3.78 lb. corn 1.56 lb. cut clover 0.26 lb. molasses	7.0	2.19	85.71
VI.	3.67 lb. corn 0.30 lb. clover	6.4	2.21	83.75
VII.	3.74 lb. corn 1.11 lb. alfalfa hay . . .	7.6	2.29	89.47

*Meal mixture by weight: 3 parts oats; 3 parts wheat bran; 3 parts wheat middlings; 2 parts linseed oil meal.

Every lot of gilts which received some kind of protein, either of plant or animal origin or a mixture of both, in addition to corn, farrowed pigs with greater average birth weight, more vitality, and carrying more fat than those on corn only. The average birth weight of 239 pigs from the twenty-five gilts receiving corn, supplemented with protein, was 21.1 per cent greater than that of thirty-eight pigs from five gilts receiving no protein in addition to corn. The number of strong pigs farrowed by the sows receiving the supplemental rations ranged from 21.3 to 36 per cent more than those from the sows receiving corn only. There was a difference of 4.87 per cent in number of pigs farrowed per sow in favor of the sows receiving the supplemental ration.

Using ten yearling sows per lot, Evvard[5] secured results similar to those he had secured previously with gilts. In this test tankage and linseed oil meal were used as protein supplements to corn in comparison to corn alone. The sows receiving .5 pound tankage and 4.17 pounds corn and those receiving 1.13 pounds linseed oil meal and 4.06 pounds corn daily farrowed pigs averaging 34.5 per cent and 22 per cent heavier respectively than those from the sows which received corn alone. The sows receiving tankage farrowed an average of 9.8 per cent more pigs, and those receiving the linseed oil meal 4.3 per cent less pigs per litter than sows on the corn ration without supplemental protein.

Two lots, each of ten Duroc-Jersey gilts, were fed as follows by Evvard, Dox and Guernsey (6): Lot I, shelled yellow corn only, 2.82 pounds; Lot II, the same amount of yellow corn plus .3 pound of blood meal daily. Gilts of Lot II farrowed an average of 8.22 pigs per litter with an average birth weight of 2.1 pounds. The gilts of Lot I, receiving corn only, farrowed an average of 7.9 pigs per litter with an average birth weight of 1.81 pounds. There were 4.3 per cent more pigs per litter farrowed by the sows receiving blood meal with corn than by those receiving corn only, and the birth weight per pig was 16 per cent greater. The addition of the blood meal to the corn ration, according to the authors, increased the vigor of the pigs 35 per cent, improved the quality of the coat 24 per cent, and the condition or fatness of the pigs 7 per cent.

In the three tests conducted by Evvard and his associates yellow or mixed corn with a predominance of yellow was used. Sodium chloride and other necessary minerals were supplied at all times. The sows were placed on the experimental rations at the time of breeding. In the three trials a total of twenty-five sows and gilts were fed corn alone and their litters compared with the litters of eighty-five sows and gilts fed on a ration of corn supplemented with various protein feeds. In each of the three trials these investigators found that sows which received a ration of corn and a protein supplement produced heavier and stronger pigs than those which received corn alone.

A comparison of a low protein ration with one comparatively high in protein, when fed to gilts from the age of six months through gestation, was reported by Davidson[2]. The low protein ration used by Davidson consisted of 188 parts barley, 188 parts corn, 16 parts bean meal, 7 parts limestone, and 2 parts sodium chloride. His high protein ration consisted of the same ingredients, in the same proportions, but with the addition of 28 pounds of blood meal. Both rations contained cod liver oil and orange juice. Six gilts were used in each group, four of which were slaughtered during the period or pregnancy and the other two were allowed to farrow.

There was no appreciable difference in the number of pigs per litter nor in the average birth weight of the pigs from the sows in the two groups. The pigs from the sows receiving less protein weighed 2.49 pounds while those from the sows receiving blood meal 2.50 pounds on the average at birth.

Summarizing the effects of the low-protein ration, Davidson observes,

> "The figure for average number at birth, 9.6, is just slightly higher than the control, 9.4 and the average weight at birth, 2.49 pounds, is equal to the control 2.5 pounds. On the other hand the average number born dead, 0.37, is twice that of the control."

Davidson's results differ from those of Evvard and his associates [4], [5], [6], in both size of litter and weight of pigs at birth. The low-protein ration used by Davidson, however, contained approximately 13.5 per cent protein.

Davidson's observations were made on smaller numbers, also which may account in part for variance in results between the two pieces of work.

Thompson[22] fed two Poland China gilts on kafir alone during the period of gestation. These gilts each farrowed 5 pigs weighing an average of 1.94 pounds. Four other Poland China gilts, sired by the same boar and out of litter-mate dams, fed on a ration of fifty parts kafir, twenty parts oats, twenty-five parts wheat shorts, and five parts tankage during pregnancy farrowed from 8 to 12 pigs per litter, weighing an average of 2.94 pounds. All of these gilts had been grown to breeding age on a well balanced ration containing adequate proteins, and received sodium chloride, bone meal and limestone at all times. The average birth weight of the pigs from the sows receiving a protein supplement in addition to kafir was 51 per cent heavier than those from the sows receiving no supplement to the ration in spite of the fact that there were more pigs to the litter. While the number of sows used in this experiment was small, both the size of litter and weight of pigs at birth compare favorably with those reported by Evvard et al [4], [5], [6].

A brief report of the work of Vestal[24] in feeding rations of grain alone, and grain rations balanced with tankage, to bred sows and gilts, shows that 66.3 per cent of pigs from sows fed corn alone and 76.7 per cent of pigs from sows fed corn and tankage were saved to weaning time. A protein supplement to corn is more important for pregnant gilts than for sows according to Vestal's report. All of the sows were fed a ration containing adequate proteins during the suckling period. No data as to birth weight or size of litter have been published.

B. Effect of Protein in the Diet on Reproduction in Rats

The effect of increasing the protein in the diet on reproduction in rats is shown by Sherman and Muhlfeld[19] who compared a ration consisting of one-sixth whole milk powder and five-sixths wheat with a ration containing one-third whole milk powder and two-thirds wheat. On the higher protein level 498 rats were born in 100 litters, 62 per cent of which were raised to weaning at which time they weighed an average of 42.3 grams, while on the lower protein level, 299 young were born in 100 litters, 48 per cent of which were successfully raised to weaning and weighed an average of 33.9 grams. Females which produced these 200 litters were placed on the experimental rations a few days before breeding and continued on the same ration until after the young were weaned. No weights were taken of the young at birth.

The recent work of Slonaker[20] with rats fed on rations ranging from 10.3 per cent of 26.3 per cent in protein failed to show an increase in size of litter by increasing the protein content of the ration. The litters studied were the total litters raised during the reproductive life of the rats which were under observation. Twenty-three female rats, raised and maintained on a ration containing 10.37 per cent protein, produced an average of 5.30 litters each, consisting of 5.26 young per litter. Twenty-one females, on a ration containing 14.2 per cent protein, produced an average of 5.76 litters of 5.15 young per litter. A ration containing 26.3 per cent protein when fed to a third group of thirteen female rats, resulted in production of only 2.92 litters each, with an average of 3.90 young per litter. Slonaker's ration which contained 10.3 per cent protein was made up of the following ingredients in parts by weight: corn starch, 5000; ground whole wheat, 2000; ground whole yellow corn, 1000; skim milk powder, 400; alfalfa leaf meal, 4000; casein, 200; meat scraps, 100; wheat germ, 300; unsalted butter, 500; yeast, 200; sodium chloride, 100; calcium carbonate, 150. The larger amounts of protein in the other two rations were supplied in the form of additional meat scraps. No birth weights are given. Slonaker believes that the optimum amount of protein for rats is about 14 per cent of the ration, and that any great deviation from that would lessen the productive capacity of both male and female.

Halverson[8] added various protein supplements of both animal and vegetable origin to a grain ration for rats and noted the effect upon reproduction. He reports that grains alone did not give satisfactory and successful growth and reproduction.

The addition of wheat embryo and ash did not improve such a ration, but the addition of a sufficient quantity of protein of either animal or vegetable origin decreased the average minimum breeding age of rats from 128 days to approximately 80 days. Halverson further observed that not only were more rats born per litter on the grain ration when supplemented with protein, but that a larger percentage of the young was raised. No records of birth weights were given.

C. Nitrogen Retention During Pregnancy

In his work with bred sows receiving an adequate protein diet, Evans(3) found that, while there was some nitrogen retention from the beginning of the period of pregnancy, only in the case of one sow that had suckled a litter and was immediately re-bred was there any considerable amount of nitrogen retained during the early stages of gestation. The greatest nitrogen retention was during the last few weeks of pregnancy. He estimates that a pig contains an average of 23.34 grams of nitrogen at birth. The sows stored an average of 1439 grams of nitrogen during the course of gestation which was six times as much as was stored in the fetuses. Evans believes that part of this stored nitrogen is used for development of the mammary glands, placental fluids, and adnexa. He made the following observations; first, ---"nitrogen is stored throughout the period of pregnancy in the sow, but mostly during the last three weeks"; second, ---"the mother stores nitrogen in excess of the requirement of the fetuses, the excess probably being stored in preparation for parturition and lactation".

Hagemann[7] working with bred bitches, found a negative nitrogen balance in the first half of the period of pregnancy and a positive balance during the last half. He concluded that during the first half of the period the embryo was developed at the expense of the tissues of the mother. Similar results were obtained with rabbits by Ver Eeke[23] when only sufficient protein to maintain the animals was used.

The the amount of nitrogen retained in the body is dependent upon the amount in the ration was shown by Jägerroos [10] in his work with bred bitches. He found that with a high-protein intake there was a positive nitrogen balance during pregnancy excepting in the second week and that a low protein intake resulted in a negative nitrogen balance throughout the gestation period with the exception of the fifth and sixth weeks, based on weekly observations. A protein level just sufficient to maintain the animal resulted in a negative nitrogen balance throughout the gestation period with the exception of the third week. The gestation period in the bitch is nine weeks.

Crowther and Woodman[1] fed pregnant cows protein in excess of the pre-pregnancy requirements and found a negative nitrogen balance during the early stages of pregnancy and only a very slight storage of nitrogen during the greater part of the gestation period, with a heavy nitrogen balance during the last three or four weeks only. They estimate that 277 grams of maternal nitrogen must have been used during pregnancy for the development of the fetus. They further observed that during parturition and for several days thereafter, the out-put of nitrogen in the milk was more than could have been stored from the feed consumed.

Mitchell[16] after a very exhaustive review of the literature on the minimum protein requirements of pregnant animals, states that two theories have been advanced as follows:

> "The effect of pregnancy upon the nitrogen metabolism of the mother has been the subject of a number of researches and the results obtained have lent support to two theories. One theory pictures pregnancy as a distinct sacrifice of the mother to the perpetuation of the species. This theory is based upon a number of studies on dogs and rabbits - - - - - - - - - - . According to this theory, the total nitrogen stored by the maternal organism during pregnancy is not sufficient to form the fetus and its membranes; thus, the maternal tissues themselves are sacrificed. As a result, during the first half of the period of pregnancy, a negative nitrogen balance persists, especially during the third and fourth week in the dog; not until the last half of pregnancy is a positive balance attained."
>
> "In direct oposition to the view that pregnancy is destructive of the maternal organism, is the view developed from a number of somewhat fragmentary observations on the nitrogen metabolism of human pregnancy, according to which the nitrogen stored in pregnancy is in great excess of the needs of the fetus for its own growth and for the growth of its protective and nourishing membranes. A nitrogen reserve is thus built up to carry the mother over the puerperium and the initial period of lactation, removing the necessity for a sacrifice of the maternal tissues."

D. Effect of Birth Weight Upon Growth in Pigs

That there is a direct correlation between the birth weight and ultimate development in pigs is shown by Kuhlman and Cole[12]. They observed birth weights of 972 pigs from yearling gilts and 1344 pigs from mature sows, at the South Dakota Agricultural Experiment Station. The mean birth weight of pigs from gilts was 2.35 pounds, and that of pigs from mature sows was 2.55 pounds. When weighed at 56 days of age, 207 pigs from gilts weighed an average of 23.02 pounds and 227 pigs from mature sows averaged 27.10 pounds. This was a difference of 9.38 pounds in favor of the pigs which were heavier at birth. These authors conclude that, up to 2.8 pounds at birth, the heavier pigs have a better chance of survival to weaning, but no further advantage was apparent for pigs weighing more than 2.8 pounds.

Lush, Culbertson and Hammond[13] reporting observations made on 322 pigs that survived to weaning time from thirty-nine gilts and five mature sows state that an advantage of an extra pound at birth gave an average advantage of seven pounds at weaning time.

E. Effect of Milk Consumption Upon Growth.

The influence of milk consumption upon rate of growth in nursing pigs was pointed out by Thompson[22]. He determined the milk consumption of individual pigs and grouped them according to the amount consumed daily. One group of nine pigs, weighing an average of 3.25 pounds at birth, consumed .35 pounds of milk per pig daily and averaged 12.9 pounds in weight at thirty days of age, and 24.9 pounds at sixty days. Another group of eight pigs averaged 3.08 pounds each at birth, consumed .51 pound of milk per pig daily, and weighed 15.4 pounds at thirty days and 31.2 pounds at sixty days of age. Although there was a small difference in birth weight in favor of the pigs which consumed the smaller amount of milk they were 2.5 pounds lighter at thirty days of age, and 6.3 pounds lighter at sixty days of age than those which consumed more milk. The advantage gained by the pigs which consumed the larger amount of milk during the suckling period was further apparent in the sixty-day period following weaning. The pigs which received the most milk while nursing weighed 62.6 pounds at one hundred twenty days of age while the other group weighed only 49.3 pounds at that age.

EXPERIMENTAL

The experiments discussed in this dissertation were designed to answer the following questions:

What is the effect of protein level in a ration fed to pregnant rats and sows upon: (a) size of litter, (b) birth weight of young, (c) post-natal growth and development of young, (d) nitrogen retention, (e) mortality of the young, (f) milk production of sows?

A. Method of Procedure

1. Rats

a. Animals

The rats used in these experiments were descendants of one male and two females, litter mates, which were obtained from Dr. H. L. Ibsen of the Kansas Agricultural Experiment Station.

b. Cages and equipment

The cages provided for the rats were made of one-fourth inch mesh hardware cloth, were thirteen by fifteen inches on the sides by twelve inches high, and had solid metal removable bottoms. The cages were bedded with shavings and cleaned semi-weekly. The colony was kept in a southeast corner room on the first floor of the Animal Husbandry building of the Oklahoma Agricultural and Mechanical College. The room, although semi-basement, had three large windows on the east and proved to be a very satisfactory location for handling rats. The room was heated in winter by overhead steam radiators and the temperature in summer caused no apparent discomfort to the colony.

Small earthen jars, two and a half inches deep and four and a half inches in diameter, were used for feeding and watering. The rats were fed and watered twice daily. More or less feed was wasted when fed in this manner, especially when the low protein ration was used. Records of feed consumption were not kept during the entire experiment, but occasional weights were taken to determine the feed consumption of the different groups from time to time.

A balance scale, accurate to one-tenth of a gram, was used for weighing the rats. The female rats used for breeding purposes in this experiment were ear-notched to facilitate identification. They were weighed when placed with the male for breeding, and after the litter was born. Weighing was done each morning between seven and eight o'clock and each evening between five and six o'clock. All litters born during the night were weighed in the morning, and all litters born during the day were weighed in the evening. The young were weighed as a litter at birth, thirty, sixty, and ninety days of age.

c. Rations

Two rations were used in this experiment and were designated as A and B. Ration A was made up to include the nutrients known to be necessary for normal growth and reproduction. Successful reproduction and rearing of young by fifteen generations of rats which were fed Ration A, without loss of size, vigor or fertility, demonstrated that this ration was highly satisfactory. Ration B contained all of the ingredients of Ration A but the percentage of protein was much lower in Ration B.

The following tables give the feeds used and the nutrients contained in each ration:

Table II

Proportion of Ingredients Used in Compounding Rat Rations

Ingredients	Ration A	Ration B
Yellow corn meal	65.0 grams	98.0 grams
Tankage (60% protein)	9.0 "	1.0 "
Linseed meal (old process)	3.0 "	0.5 "
Alfalfa leaf meal	3.0 "	0.5 "
Mineral mixture*	2.0 "	2.0 "

*The following mineral mixture, known as the McCollum salt mixture No. 185[15] was used for all rats in the experiment:

Sodium chloride	$Na\ Cl$	173 grams
Magnesium sulphate	$Mg\ SO_4$ anhydrate	266 "
Monobas. sodium orthophosphate	$Na\ H_2\ PO_4 \cdot H_2O$	347 "
Mono-calcium phosphate	$Ca\ H_4(PO_4)_2\ H_2O$	540 "
Mono-hydrogen potassium orthophosphate	$K_2\ H\ PO_4$	954 "
Ferric citrate	$Fe\ C_6\ H_5\ O_7 \cdot 3H_2O$	118 "
Calcium lactate	$Ca\ (C_3H_5O_3)_2 \cdot 5H_2O$	1300 "
Potassium iodide	$K\ I$	2 "

Table III

Percentage of Nutrients in Rat Rations*

	Ration A	Ration B
Total protein	15.29	10.12
Total fat	4.35	3.95
Total nitrogen-free-extract	60.49	67.41
Total fiber	2.70	2.29
Total ash	5.32	4.10
Total digestible nutrients	79.58	80.45
Digestible protein	12.60	7.77
Protein from corn	52.00	91.00
Nutritive ratio	1:5.31	1:9.35

*Figures taken from Morrison's Feeds and Feeding, 20th Edition.

d. Feeding methods

Experimental feeding of the rats was started on September 1st, 1928 and continued to June 1, 1934. The females weighed approximately 145 grams at the time of breeding. They were allotted as evenly as possible according to size and age into three groups at breeding time, and were placed in cages, four to each cage. One male was placed in each cage with the four females, in the evening, and was replaced by another male every twenty-four hours thereafter for a period of five days. The male rats used were the most vigorous ones obtainable from the stock colony and ranged in age from six to twelve months when used for breeding purposes. The females were separated before parturition and each was kept in a separate cage until the young were weaned at thirty days of age. The adult female was then removed from the cage and the male and female young were separated for further study. The first litter only produced by each female was used in this experiment. The stock colony was fed Ration A continuously.

The three experimental groups designated as Group I, Group II, and Group III, were fed as follows:

Group I was fed all they would consume of Ration A from the time the females were placed with the males until the young were ninety days of age.

Group II was fed Ration B from the time the females were placed with the males until the time of parturition. Ration B was replaced by Ration A the day the young were born. The females received Ration A throughout lactation, and the young of this group continued to receive Ration A until they were ninety days of age.

Group III received Ration B during the entire course of the experiment.

e. <u>Transferring litters</u>

Thirty representative litters were selected from Groups I, II and III for these studies. Litters born the same day from mothers of different groups were used. After the young of each litter were weighed and identified, part of the litter was exchanged for a like number of young from a mother of a different group.

f. <u>Metabolism studies</u>

The metabolism cages were made of one-fourth inch mesh hardware cloth on the sides and one-half inch hardware cloth on the bottom. They measure ten inches in diameter and are ten inches high. A fine screen wire was placed some two inches below the bottom of the cages to catch feces. The urine passed through the fine screen and was collected in sulphuric acid in an earthenware crock.

The feces were removed daily and dried quickly over a moderate flame. At the end of the trial the urine was carefully washed from the screen and the sides of the crock.

During the balance trials the rats were removed from the metablism cages for an hour morning and evening to be fed.

The feces were removed from the feeding cages and dried with those from the metabolism cages. Urine passed during the feeding period was not collected. Nine and one-tenth per cent of the total nitrogen excreted in the urine during the twenty-two hours in the metabolism cages was added in arriving at the total nitrogen voided in the urine.

Three metabolism trials were run on rats from each of the groups fed on Ration A and B. Four rats from each group were used in each trial. For these studies representative rats that had gained twenty grams or more during the first two weeks of pregnancy were used. All rats used in these trials produced normal litters.

The rats were given two days preliminary feeding in the metabolism cages before the four day metabolism studies were begun.

2. Swine

a. <u>Animals used</u>

Thirteen Poland China gilts, all by one sire and out of closely related dams, were selected for use in determining the effect of ration upon the birth weight and development of pigs. All gilts were bred by the Oklahoma Agricultural and Mechanical College and were raised on a ration made up of sixty-five pounds yellow corn, five pounds tankage, and thirty pounds wheat shorts.

The gilts had free run of sudan and rape pasture until placed in experimental pens. They had free access to a mixture of equal parts of sodium chloride, ground limestone and bone meal before the experiment started. The gilts were approximately eight months old when bred.

b. Rations and feeding methods

During the course of the experiment, the gilts and their pigs were kept in dry lots. The gilts were placed on experimental rations November 10, 1929 and were bred during the first heat period following that date. The pigs were weighed at birth, at 60 days, and 120 days of age. The rations were the same as used in the experimental work just reported with rats except that the mineral mixture used consisted of equal parts of common salt, steamed bone meal, and ground limestone. The The pigs had access to feed in self-feeders from the time they began to eat. They were weaned when 60 days of age.

The gilts were divided as evenly as possible into two groups which, with their litters, were designated as Group I and II. Group I received Ration A during the entire course of the experiment. Group II received Ration B during the period of gestation and Ration A from the time of farrowing until the pigs were 120 days of age.

c. Lactation studies

For the purpose of studying the amount of milk produced by sows during lactation, five representative sows, two from Group I and three from Group II were selected at farrowing time. The amount of milk produced by each sow was determined by withholding pigs from the sow until they were hungry, then allowing them to nurse all of the milk out of her udder. Using the time of that nursing as a starting point but not recording milk drawn by the pigs at that time, the pigs were allowed to nurse at four-hour intervals until a period of twenty-four hours was completed. The pigs were weighed by litters immediately before and after each nursing, and the difference in weight was taken to be the amount of milk produced by the sow at nursing. Records were made on the tenth, thirtieth, and fiftieth days after the pigs were farrowed and the average of these three days used as the average daily milk production for the sixty day lactation period.

B. Results

1. Rats

a. <u>Size of litter, birth weight, and subsequent development</u>

The rats in each group that weighed five grams or more at birth are placed in sub-group (a), and those weighing less than five grams in sub-group (b). The average weights presented in Table IV are based on weights of litters rather than of individuals. Consequently sub-groups (a) and (b) are formed on the basis of average birth weight per rat as determined by dividing litter weight by number of rats per litter. No division within a litter is made in any case.

Table IV

Size of Litter, Birth Weight, and Development of Young

Group	Average No. rats per litter	Total rats born	Average birth weight gm.	Average 30-day weight gm.	Average 60-day weight gm.	Average 90-day weight gm.	Per cent rats raised to 90 days
Ia	4.27	140	6.04	39.11	90.68	122.93	83.6
Ib	8.18	194	4.38	35.60	86.55	116.62	60.8
IIa	3.00	36	5.75	32.24	60.70	108.07	65.1
IIb	7.07	280	4.24	26.09	50.97	96.62	63.2
IIIa	2.4	21	5.66	31.94	44.11	77.01	57.1
IIIb	6.50	156	4.29	21.30	33.93	65.53	45.0

A study of Table IV reveals a positive correlation between birth weight and weight at any subsequent date. Group Ia compared to Group Ib, for instance, was 1.66 grams heavier at birth, 3.51 grams heavier at thirty days, 41.13 grams heavier at sixty days, and 6.31 grams heavier at ninety days. Group IIa likewise maintained an advantage in weight over Group IIb, as did Group IIIa over Group IIIb. This is in keeping with the work of Kuhlman and Cole[(12)], and Lush, Culbertson and Hammond [(13)], who have shown a positive correlation between the birth weight and rate of growth in pigs.

The existence of a negative correlation between size of litter and the weight of the rats at birth is suggested by Table IV. This was also brought out by Kuhlman and Cole[(12)] in their work with hogs. A study of Groups Ia and Ib, which are typical of other corresponding groups, shows rats which averaged 4.38 grams at birth were from litters averaging 8.18 rats per litter, whereas rats which averaged 6.04 grams at birth came from litters averaging only 4.27 rats per litter. The size of litter, then, influences rate of development in the young as well as average birth weight of the young. The more rapid gain made by young of small litters probably is due in part to advantage in birth weight and in part to better nourishing of individual young by the dam which has the smaller number to nourish.

b. Effect of ration on size of litter

The mean number of rats born per litter (Table V) was .30 or 5.3 per cent greater in Group I than in Group II, and .79 or 15.3 per cent greater in Group I than in Group III. These small differences have no statistical significance. The difference between the mean size of litters of Group I and II is only 1.1 times its probable error. A greater difference is found between the means of Group II and III, both of which were fed exactly alike, than between the means of Groups I and II. Here, however, the difference is only 1.45 times its probable error. It is apparent from a comparison of fifty-eight litters from mothers that were fed through pregnancy on Ration A and ninety-one litters produced by mothers which received Ration B that the effect of the protein level of Ration B upon the number of young born per litter was not significantly different from the corresponding effect of Ration A.

Absence of a significant effect of the low level of protein intake during pregnancy, only, upon size of litter is not surprising, however, if size of litter is due primarily to number and viability of ova produced and condition of the uterus as to whether favorable to implantation. These factors had been determined practically at the time the female rats were placed on the experimental ration, with little likelihood of a deleterious effect being produced by withholding a portion of the protein subsequent to the beginning of pregnancy. Apparently the low supply of protein in Ration B of this experiment was not so injurious as to cause abortion or resorption of fetuses, which are the most probable methods by which size of litter would be reduced should any reduction occur as a result of protein deficiency in the ration of the pregnant female.

Table V

Effect of Ration Upon Number of Rats per Litter, and Weights at Birth, 30, 60 and 90 Days of Age.
(All weights are in grams)

	Group	No. of litters	Total number of rats	Mean number or weight		Standard deviation
Number rats per litter	I	58	334	5.97	±.190	2.20
	II	58	316	5.67	±.203	2.30
	III	33	177	5.18	±.270	2.27
Birth weight (grams)	I	58	334	5.08	±.031	.85
	II	58	316	4.35	±.018	.47
	III	33	177	4.38	±.015	.30
30-day weight (grams)	I	58	270*	35.47	±.208	5.06
	II	58	230*	25.67	±.235	5.28
	III	33	101*	21.60	±.265	3.95
60-day weight (grams)	I	58	243*	88.10	±.467	10.79
	II	58	203*	50.22	±.318	6.71
	III	33	91*	33.66	±.416	5.88
90-day weight (grams)	I	58	243	119.40	±.240	5.44
	II	58	203	99.06	±.380	8.04
	III	33	91	68.35	±.480	6.42

*Reduction in number of rats in each group during any portion of the 90-day period was due to losses from death.

c. Effect of ration upon birth weight of young

The birth weight of rats was 16.8 per cent greater in Group I than in Group II, and 16 per cent greater in Group I than in Group III (Table V). The difference between the mean birth weights in Group I and Group II was twenty times its probable error and must not have been a chance result.

Only ten litters, with an average of eight rats per litter, in Group I averaged less in weight at birth than the mean of Group II, and only twelve litters comprising thirty-six rats in Group II had an average weight at birth greater than the mean of Group I.

These results are similar to those reported by Evvard et al (4), (5), (6) and Thompson[21] on swine, but differ from those of Davidson[2] who concluded that increasing the protein in the ration for pregnant gilts beyond that contained in his ration of lower protein content did not affect the weight of the pigs at birth. Davidson's low protein ration, however, contained 3.5 per cent more protein than the ration of corn alone used by Evvard and associates, and 3 per cent more protein than Ration B of this experiment.

d. Effect of ration received during pregnancy on growth of the young while nursing

Young rats in Group I, weighing 16.8 per cent more at birth than those in Group II (Table V), were 38.2 per cent heavier at thirty days of age. This difference developed in spite of the fact that both groups received Ration A during this period of nursing. The young of Group III, whose dams received Ration B during both pregnancy and lactation, made even poorer growth than the young in Group II. The mean weight of Group I was 64.2 per cent heavier than that of Group III at thirty days of age, at which age all young were weaned. The young in Group I gained 47 per cent more during the suckling period than the young in Group II, and 80 per cent more than the young in Group III during the same time. It should be borne in mind that management of Groups I and II differed only as to rations fed to the dams before birth of the young. Thus any difference between rates of growth in the young of Groups I and II while nursing must be attributed to a nutritional influence which began before birth of the young, and which continued to be effective either in the capacity of the young to gain or in the capacity of the dam to nourish her young.

e. Effect of ration received during pregnancy upon growth of young after weaning

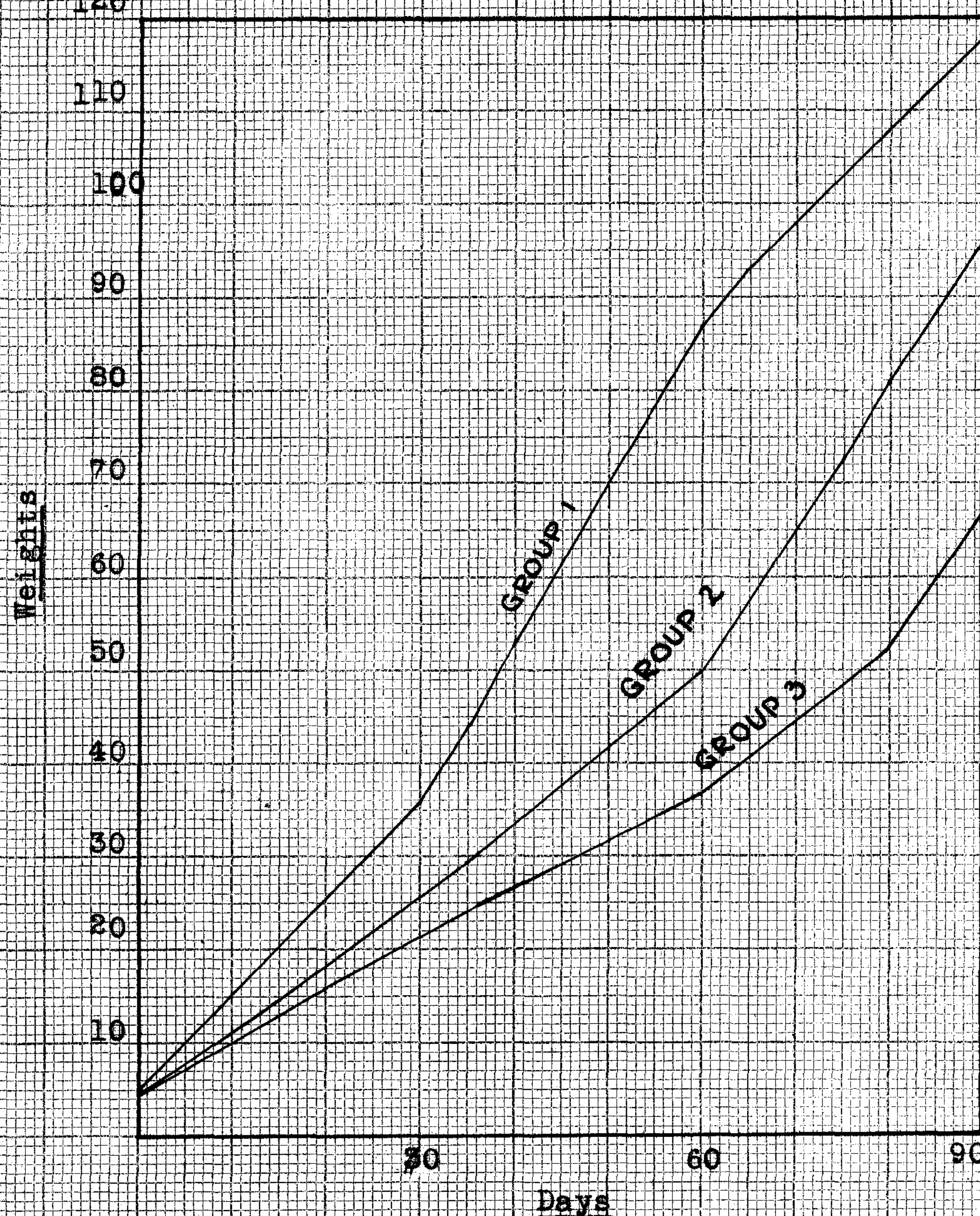
The rats in Group I were 16.8 per cent heavier than those in Group II at birth, 38.2 per cent heavier at thirty days, and 75.5 per cent heavier at sixty days, but only 20.5 per cent heavier than those of Group II at ninety days of age. The only difference in treatment of these two groups was in the rations received during pregnancy. Females of Group I received the adequate Ration A during the period of gestation whereas those of Group II received Ration B, which was low in protein content, during pregnancy. Both groups received Ration A from the time of birth of the young until they were ninety days of age. As the difference between the mean weights of Group I and II at thirty, sixty and ninety days was twenty, thirty-one and forty-six times their probable errors, respectively, the results seem to show unmistakably that a low protein ration received in pre-natal life did have an inhibitory effect upon the growth of the rat after birth. That this handicap in the early life of the rat might eventually have been overcome is suggested by the comparative rates of growth in Groups I and II by periods as shown in Table VI.

Table VI
Average Daily Gain of Young by Periods

	Average daily gain (grams)		
Group	First 30 days	30 to 60 days	60 to 90 days
I	1.02	1.75	1.00
II	.71	.82	1.53
III	.57	.50	1.03

The young in Group I gained 47 per cent faster than the young in Group II during the thirty-day period of nursing. In the second period, between the ages of thirty and sixty days, the young in Group I gained 113.3 per cent faster than those in Group II. The rats in Group II showed marked improvement, between the ages of sixty and ninety days, however, and gained 53 per cent faster than those in Group I during this time. Group I dropped from an average daily gain of 1.75 grams made in the thirty to sixty day period, to a daily gain of 1.00 grams in the next thirty-day period. Group II increased its gains from .82 grams to 1.53 grams daily for the corresponding periods. The rats in Group I were much fatter and more mature than those in Group II at sixty days of age, which no doubt accounts for their decrease in rate of gain after reaching that age. This is the normal behavior of rats according to King[11], who reported that 281 inbred rats, on satisfactory rations, gained 1.64 grams daily from thirty to sixty days of age, and 1.08 grams daily only from the sixtieth to the ninetieth day. The rats in Group II deviated from the normal growth curve by a very slight increase in gain during the first thirty days after weaning, followed by a decided increase during the second thirty days after they were weaned. According to Davidson[2], Osborne and Mendel[17], and others, this rapid, though delayed, growth is to be expected after a period of retardation.

The rats in Group III did very poorly throughout the experiment. Their gains were small, their coats rough, and they were thin in flesh and very restless. They weighed 42.75 per cent less at the age of ninety days than the rats in Group I. (See Graph 1.)



Graph No. 1. Weight of Rats, in Grams.

In order to more clearly differentiate between the effects of birth weight and of ration upon development, comparisons of Groups Ib, II, and IIa are made in Table VII. Group Ib is comprised of those young in Group I which averaged less than five grams each (based on litter weights) at birth, Group II includes all young in that entire group, and Group IIa is made up of young in Group II which weighed five or more grams each at birth.

Rats in Group Ib had approximately the same average birth weight as those in the whole of Group II. A comparison of their subsequent development discloses a continuous advantage of Group Ib in gains from birth until ninety days of age, when the rats were removed from experiment. The disadvantage of Group II in this respect is interpreted to be the result of an unfavorable carry-over effect of Ration B received by dams of Group II during the period of pregnancy. Additional support is lent to this deduction by a comparison of the development of Groups Ib and IIa.

Table VII
A Comparison of Group Ib With Groups II and IIa

Group	Average size of litter	Total rats	Average birth weight	Average 30-day weight	Average 60-day weight	Average 90-day weight
			gm.	gm.	gm.	gm.
Ib	8.18	194	4.38	35.60	86.55	116.62
II	5.66	316	4.32	25.67	50.22	96.24
IIa	3.00	36	5.75	32.24	60.70	108.07

The statistical significance of differences in weight of Groups Ib and II at various ages is shown by the following values which represent differences divided by their probable errors: Birth, 1. (no significance); thirty days, 6.7; sixty days, 55.8; ninety days, 22.6. There was no important difference between birth weights of the two groups, but differences between all subsequent weights were significant, the one at sixty days being most pronounced. Although rats in Group IIa had an advantage over those of Group Ib of 1.37 grams in average birth weight they were over-taken in weight by Group Ib in the course of post-natal development and weighed 8.55 grams less than the latter at ninety days of age. The advantage of 1.37 grams in birth weight of Group IIa was insufficient to overcome the handicap imposed by Ration B during their pre-natal life.

f. Effect of ration upon mortality of the young

The greater pre-natal mortality of young in Groups II and III combined (Table VIII) than in Group I, and the greater post-natal mortality in Group III than in Group I are further results of the inadequacy of protein in Ration B.

Table VIII
Effect of Ration Upon Mortality of the Young

Group	Total rats born	Rats born alive: Number	Rats born alive: Per cent of total	Rats raised to 90 days: Number	Rats raised to 90 days: Per cent of those born alive
I	334	284	88.6*	243	86.8*
II	316	---	-- -	203	86.7*
III	177	---	-- -	91	64.1*
II and III	493	394	76.7*	---	-- -

*Weighted means.

The difference of 11.9 per cent more young born alive in Group I than in the combined Groups II and III is 7.08 times its probable error. Of the young born alive, those in Group I had no appreciable advantage over those in Group II in survival to ninety days of age. The young in Group I did, however, exceed those in Group III in survival to ninety days of age by 22.7 per cent. This difference of 22.7 per cent survival in Group I over Group III is 9.19 times its probable error. A similar difference exists between the mean survivals in Groups II and III. The statistical significance of these differences places the odds heavily against their being due to chance alone.

According to these observations the feeding of Ration B during pregnancy resulted in greater pre-natal mortality than occurred when Ration A was fed during the same time. The feeding of Ration B to lactating mothers and their young resulted, however, in heavy post-natal death losses. There was no appreciable carry-over effect of Ration B when fed during pregnancy if exchanged for Ration A at the time of birth of the young.

g. The effect of transferring rats at birth from mothers of one group to mothers of another group

In attempting to determine the reason for the failure of young born from mothers receiving Ration B during pregnancy to respond more readily when the mothers were placed on Ration A, the studies found in Table IX were made. In this work part of a litter from each of the three groups: I, II and III was exchanged at time of birth for a like number of rats born the same day to a mother in another group. Each mother, as a result of this exchange, nursed part of her own litter and part of a litter from a mother in another group.

Table IX

The Effect of Transferring Rats at Birth from Mothers of One Group to Mothers of Another Group

Group	I	II	III	IV	V	VI
No. of rats	25	25	20	20	22	27
Average birth weight, gm.	5.2	4.3	4.3	5.2	4.3	5.1
Average weight at thirty days of age, gm.	37.8	30.8	21.6	30.4	29.1	33.0
Average daily gain first thirty days, gm.	32.5 ± .6	26.5 ± 0.7	17.3 ± 0.5	25.2 ± 1.2	24.7 ± 0.9	27.9 ± 0.9
Average weight at 60 days of age, gm.	95.0	63.7	49.5	62.1	70.7	85.7
Average gain from thirty to 60 days of age, gm.	58.2 ± 2.0	31.9 ± 1.8	28.3 ± 2.0	31.7 ± 2.9	41.6 ± 2.1	52.8 ± 1.3
Average weight at ninety days of age, gm.	143.2	109.2	74.1	97.7	117.8	121.6
Average gain from 60 to 90 days, gm.	48.2 ± 3.5	46.6 ± 1.8	29.6 ± 3.6	32.6 ± 2.1	47.2 ± 2.6	46.0 ± 1.7

In the preceding table in addition to the three groups already discussed there have been added three additional groups. Group IV includes the rats that were transferred at birth from mothers in Group I to mothers in Group III. In Group V are the rats that were transferred at birth from mothers in Group III to mothers in Group I. In Group VI are the rats that were born to Group I mothers and transferred to Group II mothers.

Using Group I as a standard for comparison, it was found that the rats in Group III, although only 17.6 per cent lighter at birth than those in Group I, gained 46.8 per cent less during the thirty day nursing period. When placed on the Group I mothers, however, as shown in Group V, the rats from Group III gained only 24.0 per cent less than those in Group I. This difference was more than can be accounted for by the difference in birth weight.

On the other hand, when rats in Group I were transferred to mothers in Group III, the gains for the thirty day nursing period were 22.3 per cent less than those for the rats remaining on their own mothers in Group I.

The rats transferred from Group I to Group II gained faster than those transferred from Group I to Group III but still gained 14.2 per cent less than the rats in Group I.

The difference in gain in weight between Groups V and II was not statistically significant.

Although the rats in Group V, that had been transferred from Group I to Group II, made better gains than the rats remaining in Group II their gains were still 14.2 per cent less during the suckling period than those of Group I.

These data would indicate that the unsatisfactory gains of the young from mothers fed on Ration B during pregnancy were partly due to pre-natal influence and partly to some other cause.

h. Effect of ration on nitrogen retention in pregnant rats

In each of the three tests shown in Table X the amount of nitrogen retained by pregnant rats during the third week of pregnancy was definitely less when Ration B was fed than when Ration A was used. This was not due entirely to lack of protein in the ration as the rats on the low protein ration actually passed in the urine from 9.3 per cent to 17.5 per cent more of the total nitrogen ingested than the rats on Ration A.

The protein digestion was also less complete in the rats on Ration B than those on Ration A since from 7.9 to 13.7 per cent more of the nitrogen ingested was passed in the feces.

According to Mitchell (16), rats receiving low-protein feeds of all kinds, excepting potatoes, retain a larger per cent of their protein than those on a higher protein level. McCollum, (14) however, found that when corn was fed

Table X

Effect of Ration on Nitrogen Retention in Pregnant Rats

(All feed given in grams and nitrogen in milligrams)

Ration fed	Ration A^{1}*	Ration A^{2}	Ration A^{3}	Ration B^{1}	Ration B^{2}	Ration B^{3}
Number of rats	4	4	4	4	4	4
Average weight of rats	152	147	175	158	156	180
Days on test	4	4	4	4	4	4
Average daily consumption of feed	11.6	9.9	11.3	12.9	9.9	10.5
Total nitrogen intake**	4486	3831	4420	3696	2807	2713
Total urinary nitrogen excreted**	1275	991	1788	1396	1020	1572
Total fecal nitrogen excreted**	712	516.5	771.2	880	676	843.2
Total nitrogen excreted**	1987	1507.5	2560	2279	1696	2416.0
Total nitrogen retained**	2499	2324	1860.8	1420	1111	297.6
Av. daily retention of nitrogen per rat	156.2	145.3	116.3	88.7	69.4	18.6
Per cent of nitrogen ingested retained	55.7	60.7	42.1	38.4	39.6	11.0
Per cent of nitrogen ingested excreted in urine	28.4	25.9	40.5	37.7	36.3	58.0
Per cent of nitrogen ingested passed in feces	15.9	13.5	17.4	23.8	24.1	31.1

*Numbers refer to groups of rats on which these were made at the same time.

**Total of four rats for four-day period.

to pigs as the sole ration, that only 23 per cent of the protein in the feed was retained but when each pound of corn was supplemented with 1.3 pounds of skim milk, 62 per cent of the protein in the ration was retained. An increase of digestible protein, according to these authorities, from 7.1 per cent to 12.6 per cent of the ration fed, increased the retention of protein by the pig from 23 to 62 per cent. McCollum attributes the low retention of protein from corn to its poor quality, it being deficient in some of the essential amino acids.

It is pointed out elsewhere in this paper that the inefficiency of Ration B might be due, at least in part, to its deficiency in some of the necessary amino acids. If McCollum is correct in his assumption that the per cent of protein retained by the pig increases when the quality of the protein is improved, it seems safe to assume that the lower percentage retention of nitrogen by rats on Ration B was due to a deficiency of some of the amino acids. According to Evans[3], bred gilts require a storage of six times as much protein during pregnancy as is necessary for the development of the fetus, the additional protein being used for the development of the mammary glands, placental fluids, and adnexa.

The works of Hagemann[7], Jägerroos[10] and Ver Eeke[23], indicate that nitrogen must be stored during pregnancy in excess of that for development of the embryo, and that stored nitrogen in the body of the mother may be used for development of the fetus and associated materials preparatory to parturition.

Although sufficient data are not available in this experiment to warrant definite conclusions, it seems probable that the inability of the rats and gilts in Group II to nourish their young satisfactorily, during the period of lactation, was due to the inability of the mother to retain sufficient nitrogen from Ration B to develop normal fetuses and allied substances without drawing heavily upon the proteins stored in her body. The body proteins, being thus depleted during the gestation period, necessarily were replenished from the ration later if the mother assumed normal metabolism. When Ration A was supplied during lactation to such a mother, part of the protein in the ration of necessity was used to replace that lost from the body during gestation, leaving an insufficient amount available for milk production. This seems to be a plausible explanation for part of the unsatisfactory results secured when rats and gilts were fed during pregnancy on Ration B which contained only 10.12 per cent protein which was probably inferior in quality.

2. Swine

a. Effect of ration on size of litter, birth weight, and subsequent development

The average number of pigs farrowed per litter (Table XI) differed only .3 pig in the two groups. Although this difference is in favor of Group I, which received an adequate supply of protein at all times, its statistical significance is negligible in view of the small number of litters involved.

Table XI
The Effect of Ration When Fed to Pregnant Gilts Upon Birth Weight and Growth of the Pigs

Group	Ration	Gilts per group	Pigs farrowed per group	Av. pigs farrowed per litter	Pigs Surviving 60 day	Pigs Surviving 120 day	Av. weight per pig (pounds) Birth	Av. weight per pig (pounds) 60da.	Av. weight per pig (pounds) 120da.
I	A continuously	6	57	9.0	40	40	3.10	32.02	70.91
II	B-prenatal A-postnatal	7	61	8.7	41	41	2.71	22.74	52.00

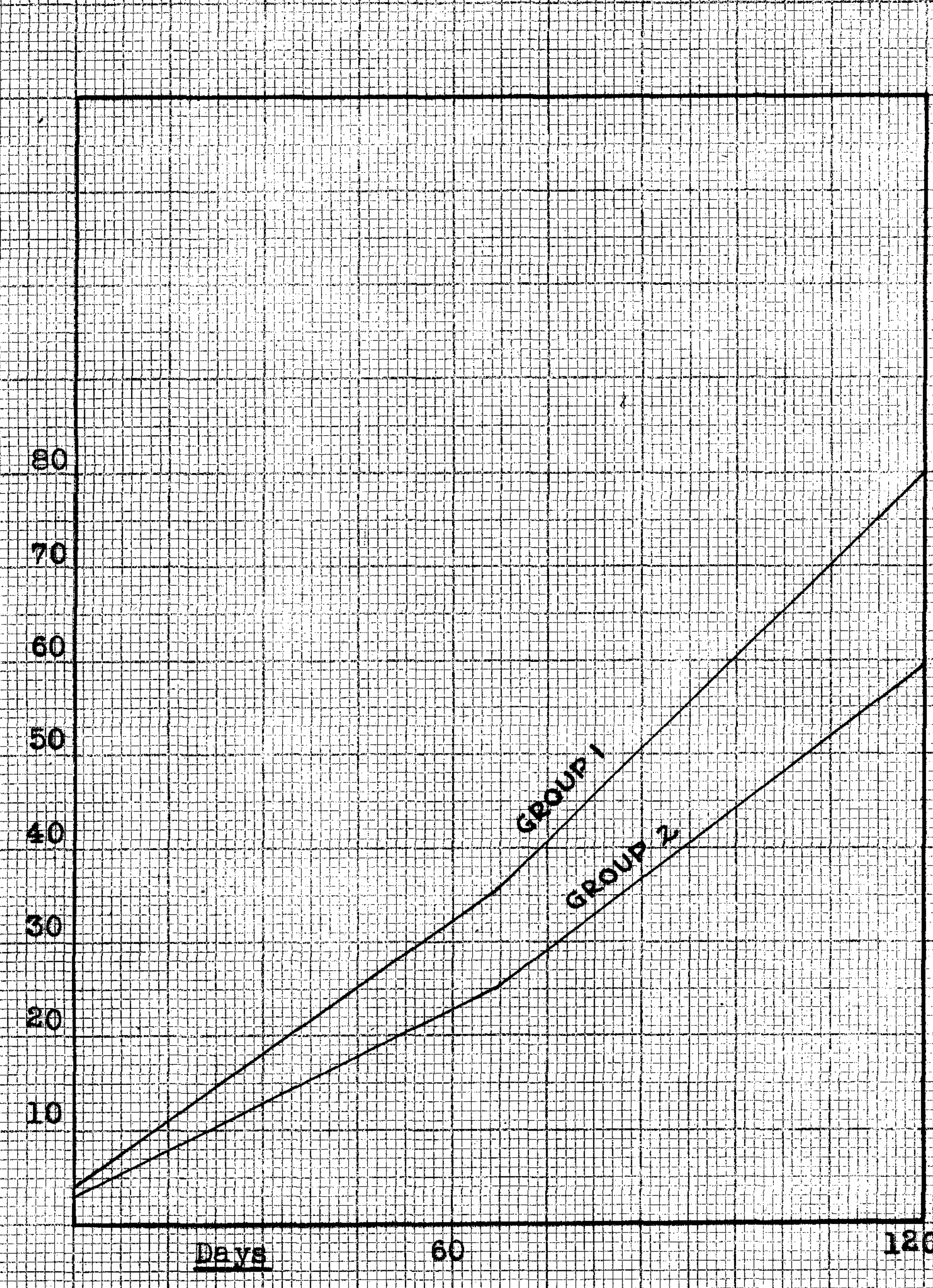
The pigs in Group I were 14.3 per cent heavier at birth, 41 per cent heavier when weaned at 60 days of age, and 32.3 per cent heavier when 120 days of age than those in Group II. The pigs in Group I gained 44.7 per cent faster from birth to weaning than those in Group II. During the period from weaning to 120 days, the pigs in Group I out-gained those in Group II, 32.7 per cent. These differences in birth weight and growth in favor of Group I, which was adequately supplied with protein in both pre-natal and post-natal life of the young, point clearly, insofar as small numbers are indicative, to an unfavorable influence on Group II which began with the feeding of a ration of low protein content during pregnancy, and which continued to affect the young directly or indirectly in post-natal life. (See Graph 2).

b. Effect of ration received during pregnancy upon lactation in the sow

The principal cause of failure of pigs, whose dams received too little protein during pregnancy, to gain normally while nursing, even when their dams received ample protein at all times after farrowing is suggested by records of milk production which are summarized in Table XII.

Sows in Group I received Ration A, which contained an adequate supply of proteins, throughout pregnancy and lactation. Those in Group II received Ration B, which was deficient in quantity of proteins, throughout pregnancy but received Ration A the same as Group I during the lactation period.

The two sows from Group I produced an average of 265 grams of milk per pig in twenty-four hours, and the three sows from Group II produced an average of only 177.8 grams per pig for the same period of time. This was 49.4 per cent more milk on the average for each pig in Group I than for those in Group II.



Graph No. 2. Weight of Pigs, in Pounds.

Table XII
Effect of Ration Received During Pregnancy on Milk Production of Sows

	Number of pigs farrow-ed	Total grams milk per sow 24 hours	Av. grams milk per pig 24 hours	Av. Birth weight (lbs.)	Av. 60-day weight (lbs.)	Av. 120-day weight (lbs.)
Sow No. 1 Group I	7	1903	271.9	3.15	32.55	72.76
Sow No. 2 Group I	6	1549	258.1	3.22	31.44	72.23
Average for Group I	6.5	1726	265.7	3.18	32.27	72.52
Sow No. 1 Group II	5	569	113.8	2.79	19.58	45.78
Sow No. 2 Group II	6	1380	230.0	2.88	29.27	66.47
Sow No. 3 Group II	10	1783	178.3	2.60	23.11	53.16
Average for Group II	7.0	1244	177.8	2.75	23.97	55.20

The pigs in Group I were 15.5 per cent larger at birth than those in Group II and gained 33.1 per cent faster during the sixty-day nursing period, but only 28.8 per cent faster for sixty days after weaning.

One sow, No. 2, in Group II, with a litter of six pigs, 9.7 per cent lighter at birth than the average for Group I, produced an average of 230 grams of milk daily for each pig, which was only 13.4 per cent less than the average for Group I. These pigs also made a correspondingly greater growth than the other pigs in Group II, gaining only 8.9 per cent less than the average of Group I during the nursing period and 7.6 per cent less for sixty days following weaning.

These results, while embracing a comparatively small number of animals, show that the gilts in Group II, receiving Ration B during the period of pregnancy were not able to produce as much milk as were the sows in Group I even though they received the same ration after farrowing as those in Group I received. It may be that there was a depletion of the proteins of the sow's body when she received Ration B during pregnancy which rendered her incapable of acquiring sufficient proteins from Ration A to restore those lost by her body and to produce milk satisfactorily, also. The rate of growth, especially during the suckling period, according to these results, is determined largely by the amount of milk ingested by the pig.

DISCUSSION

Some rather significant deductions can be made from a study of the work presented in this manuscript.

The number of young at birth per litter was not materially affected by the ration received by the mother during gestation. Both rats and sows that were fed on a ration containing only 10.12 per cent protein from time of breeding and through the entire period of gestation produced approximately the same number of young per litter as similar mothers receiving a ration containing 15.29 per cent protein during pregnancy. This is no doubt a normal situation as all females had received the same ration up to or within a few days of the date of conception.

Rats and sows fed during pregnancy on a ration insufficient in protein gave birth to young that were significantly lighter in weight than those produced by similar females that had received a normal ration during the same period. The average birth weight for rats from mothers fed on the higher protein level was more than 16 per cent heavier than those from the low protein-fed mothers and the difference between the mean birth weights of the two groups by litters was twenty times its probable error. The pigs from sows fed on the ration containing 15.29 per cent protein were 14.3 per cent heavier at birth than those from sows receiving only 10.12 per cent protein in their ration.

From the preceding paragraph it is seen that rats and sows fed during pregnancy on Ration B, which contained only 10.12 per cent protein, produced young which were lighter in weight at birth than the young which were produced by the rats and sows fed during pregnancy on Ration A that contained 15.29 per cent protein. Does this handicap of approximately 16 per cent lighter birth weight retard the growth of the young after birth? This experiment clearly shows that the 16% lighter birth weight does retard the growth of the young after birth.

It has been pointed out in the discussion of Table IV, however, that the greater weight at birth, although a decided advantage during growth, is not sufficient to account for all of the difference found in the growth of the young in Groups I and II. (See Table VII) The only other factor in which the Groups, I and II, differ is in the amount and possibly quality of protein received during pregnancy, as all rats and sows were fed exactly alike before pregnancy and after the birth of the young.

The low protein level of Ration B when fed to pregnant rats adversely affected the per cent of rats born alive but did not influence the ability of the young to survive after birth. The rats receiving the 15.29 per cent protein ration produced 11.9 per cent more living rats at birth than those receiving the lower protein level, but the number born alive, surviving to maturity, was not significantly greater.

The work presented in this thesis suggests an explanation for the fact that rats and sows when fed during pregnancy on a ration inadequate in quantity and quality of protein not only produce young that are lighter in weight at birth but are unable to nourish their young satisfactorily during lactation, even though receiving an adequate ration at that time.

A study of Table X brings out the fact that rats in the third week of pregnancy retained more nitrogen when fed on Ration A than those fed on Ration B. The rats from the mothers receiving the higher level of protein weighed 16.8 per cent more at birth than those from the mothers receiving the 10.12 per cent protein level, but retained an average of over 100 per cent more nitrogen. Either more nitrogen was stored than necessary for the development of the fetus when a ration containing 15.29 per cent protein was fed or the body proteins of the mother were called upon to help nourish the fetus when a ration containing only 10.12 per cent protein was used. In either event the mothers fed on Ration B, low protein, during pregnancy, retained less nitrogen in their bodies during gestation than the mothers on Ration A of the higher protein level.

The low nitrogen retention during pregnancy of rats fed on a low protein ration might account not only for the inability of the mother to properly nourish her young during the period of lactation, but might also explain the lighter weight of the young at birth. This belief is further substantiated by the fact that the sows receiving the ration adequate in protein during both pregnancy and lactation, produced 38.8 per cent more milk for each pig than the sows fed the low protein ration during pregnancy and the adequate protein ration during lactation. Further evidence to support this hypothesis is found in Table IX, where it is shown that a portion of a litter of rats from one Group, when exchanged for a portion of a litter from another Group during the nursing period behaves, as far as rate of growth is concerned, to a marked degree as does the remaining portion of the litter which was not so exchanged.

In this test the rats nursing a mother that was fed during pregnancy on a low protein ration made unsatisfactory gains while nursing in spite of the fact that the mother was receiving a satisfactory ration at that time. The poor gain resulted regardless of whether the rats were her own or were transferred from another mother. When transferred from a Group I mother, however, the gains were significantly greater than those of her own young. The reverse was true when the young from Group II mothers were nursed by Group I mothers. In this case the young from Group II mothers gained decidedly faster than their litter mates that remained with their own mother but significantly less than the young of the Group I mother.

That a low protein ration such as used in this experiment when fed to pregnant rats or sows will inhibit the ability of such females to produce a normal number of living young of a normal birth weight, and to properly nourish their young seems certain. While the data are too meager to justify conclusions, all experimental evidence herein presented points to the probability that such inhibition is largely due to a deficiency of nitrogen storage during pregnancy in case the low protein ration is used. Being deprived of protein during pregnancy the mother must use the proteins of her tissues to nourish the fetus. After parturition she uses the extra protein in the improved ration, that normally would go to the production of milk, for the rebuilding of the protein tissues of her body. Further work needs to be done on the effect of ration upon nitrogen retention and its effect upon milk production.

SUMMARY

In this experiment two rations composed of yellow corn, tankage, linseed meal, alfalfa leaf meal and minerals were used. Ration A was designed to meet all the requirements for normal growth and reproduction in rats and swine by the inclusion of all the known nutrients in sufficient quantities and of proper quality. This ration contained 15.29 per cent protein.

In Ration B the same ingredients were included but the protein content was reduced to 10.12 per cent by increasing the per cent of corn in the ration.

The rats at time of breeding were divided into three groups and designated as Groups I, II and III. The sows were divided into Groups I and II and fed the same as the rats of corresponding groups.

Group I was fed on Ration A throughout the experiment.

Group II was fed on Ration B during the period of pregnancy and Ration A thereafter.

Group III received Ration B at all times.

There was no significant difference in the number of young born per litter of mothers fed during pregnancy on Rations A and B.

There was a positive correlation between the birth weight of rats and the weight at thirty, sixty and ninety days of age.

A large number of rats per litter resulted in a correspondingly lighter birth weight per rat.

Rats when fed through the period of pregnancy on Ration A gave birth to young that were 16.5 per cent heavier than those of similar mothers fed during the same period on Ration B. When gilts were fed on Ration A during pregnancy the pigs were 14.4 per cent heavier at birth than the pigs from sows that were fed on Ration B during the same period.

The nursing young of rats from mothers that were fed Ration A during pregnancy and lactation gained 47 per cent faster during the thirty day nursing period than the young from mothers that were fed during the period of pregnancy on Ration B and during lactation on Ration A. During the sixty-day nursing period the pigs nursing gilts fed continuously on Ration A gained 44.7 per cent faster than the pigs on gilts fed during pregnancy on Ration B, and during the nursing period on Ration A.

For a period of thirty days following weaning, the young rats in Group I gained 113.3 per cent faster than those in Group II but from sixty to ninety days of age, the average daily gains of young rats in Group II was 53 per cent faster than those in Group I. For a period of sixty days following weaning, the pigs in Group II gained 11.32 per cent faster than those in Group I.

The rats in Group III, fed continuously on Ration B, made unsatisfactory gains during the entire experiment. From sixty to ninety days of age, however, they showed improvement in rate of gain.

Where the mothers were fed on Ration B during pregnancy, 11.9 per cent more rats were stillborn than where similar mothers were fed on Ration A during the same period.

Rats during the third week of pregnancy, on Ration A, stored approximately twice as much nitrogen as did rats during the same period on Ration B. Not only did the pregnant rats on Ration A store more total nitrogen but also retained from 17.4 to 31.1 per cent more of the nitrogen ingested than did the rats on Ration B. Protein digestion was also more complete as from 7.9 to 13.7 per cent more nitrogen was passed in the feces of the pregnant rats on Ration B than from those on Ration A.

Young rats from mothers of Group I fed during pregnancy and lactation on Ration A gained 79 per cent faster while nursing than the young from mothers in Group III fed on Ration B during the same periods. When part of the young of a Group I mother were transferred at birth to a mother of Group III the gains during the nursing period were only 23.3% less than the gains of the remainder of the litter left on the Group I mother. Likewise when part of the young were transferred from a Group III mother to a Group I mother the gains were only 24 per cent less than the gains of Group I mothers' own young.

When transferred from a Group I mother to a Group II mother the young made gains only 14.2 per cent less than the young not transferred.

LITERATURE CITED

(1) Crowther, Charles and Woodmán, H. E.
A study of nitrogen metabolism in the dairy cow.
Jour. Agr. Sci. 12:40-56. 1922.

(2) Davidson, H.R.
Reproductive disturbances caused by feeding protein-deficient and calcium-deficient rations to breeding pigs. Jour. Agr. Sci. 20:233-264. 1930.

(3) Evans, R.E.
Protein and mineral metabolism in pregnant sows on a normal or high calcium compared with a calcium-deficient diet. Jour. Agr. Sci. 19:752-791. 1929.

(4) Evvard, J.M.
Nutrition as a factor in fetal development.
Ann. Rpt. Amer. Breeder's Assoc. 8:549-560. 1912.

(5) Evvard, J.M.
The value of different pasture crops for growing pigs and brood sows. Proc. Amer. Soc. An. Prod. 1913.

(6) Evvard, J.M., Dox, A.W., and Guernsey, S.C.
The effect of calcium and protein fed pregnant swine upon the size, vigor, bone, coat and condition of the offspring. Amer. Jour. Phys. 34:3, 312-325. 1914.

(7) Hagemann, O.
Neber Eiweissumsatz während der Schwangerschaft und der Lactation. Arch. f. Anat. and Physiol.
Physiol. Abt. 1890: 577-581. 1890.

(8) Halverson, J.O.
Effect of diets upon growth, reproduction, and rearing of young with laboratory animals. 49th Ann. Rpt.
N.C. Agr. Exp. Sta. p.47. 1926.

(9) Henry, W.A. and Morrison, F.B.
Feeds and Feeding. 18th Edit. p. 728. The Henry and Morrison Co., Madison, Wis. 1923.

(10) Jägerroos, B. H.
Studien Über den Eiweiss-, Phosphor-und Saezumsatz der Gravidität. Arch. f. Gynak. 67:517-590. 1903.

(11) King, Helen Dean.
A further study of the effects of inbreeding on the growth and variability in the body weights of the albino rat. Jour. of Expt. Zool. 29:71-111. 1919.

(12) Kuhlman, A.H. and Cole, L.J.
Birth-weight important factor in swine production. Ann. Rpt. Wis. Agr. Exp. Sta. Bul. 405, p.63-4. 1929.

(13) Lush, Jay L., Culbertson, C.C., and Hammond, W.E.
Big pigs at birth mean big pigs at weaning time. Swine World. 19:4. Nov. 1931.

(14) McCollum, E.V.
The value of the proteins of the cereal grains and of milk for growth in the pig, and the influence of the plane of protein intake on growth. Jour. Biol. Chem. 19:323-333. 1914.

(15) McCollum, E.V. and Simmonds, N.
A study of the dietary essentials, water-soluble B, in relation to its solubility and stability towards reagents. Jour. Biol. Chem. 33:55-89. 1918.

(16) Mitchell, H.H.
The minimum protein requirements of cattle. Bul. Natl. Res. Coun. No. 67. 1929.

(17) Osborne, T.B. and Mendel, L.B.
The resumption of growth after long-continued failure to grow. Jour. Biol. Chem. 23:439-454. 1915.

(18) Perkins, A.E.
Protein studies. 48th. Ann. Rpt. Ohio Exp. Sta. p. 115-116. 1928-29.

(19) Sherman, H.C. and Muhlfeld, Marie.
Influence of food upon mother and young during the lactation period. Jour. Biol. Chem. 53:41-52. 1922.

(20) Slonaker, James R.
The effect of different per cents of protein in the diet: 1 Growth; 11 Spontaneous activity. Amer. Jour. Phys. 96:547-561. 1931.

(21) Thompson, C.P.
Effect of protein and mineral on the development of swine. Okla. Agr. Exp. Sta. Bul. 144. 1922.

(22) Thompson, C.P.
Effect of milk production upon the growth of suckling pigs. Proc. Amer. Soc. An. Prod. 266-267. 1931.

(23) Ver Eecke, A.
Les échanges materiels dans leurs rapports avec les phases de la vie sexuelle.
Mém. Cour. et autres Mém. de L'Acad. Roy. Med. de Belgique. v. 15, no. 7. 1901. (Original not seen. Cited in Jägeroos (10) p. 517.)

(24) Vestal, C.M.
Corn, oats and tankage suitable ration for brood sows. 41st Rpt. of Dir. of Indiana Agr. Exp. Sta. p. 36. 1929.

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